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Incubation Experiments with Turkey Eggs

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Relatively little experimental work on the incubation of turkey eggs has been published. This bulletin includes the results of two years' experimental work conducted in the incubation laboratory at the Kentucky Agricultural Experiment Station with eggs from Bronze turkeys. Some of these experiments were published in research journals (as noted in the references), but are presented here so that they may be more available to poultrymen.

GENERAL PROCEDURE

A major portion of the eggs used in these experiments came from the flock of Bronze turkeys of R. E. Nute, Valley Station, Kentucky, and were shipped approximately 100 miles by express to the Station laboratories. All eggs were gathered daily and placed, small end down, in egg cases equipped with duck-egg fillers. Each case held two hundred eggs. Each day's gathering was kept separate so that the eggs might be distributed among the various lots (in the incubator) according to the age of the egg. During the holding period, the eggs were kept in a well-ventilated cellar. No eggs were more than eight nor less than two days old when set. A few of the eggs came from the Robinson Substation, Quicksand, Kentucky. They were shipped approximately 100 miles to the incubation laboratories.

The breeding flock of Mr. Nute was fed cracked corn and wheat each evening and a mash of the following formula was available in self-feeders at all times thruout the year:

Ground yellow corn	200	pounds
Wheat bran	100	pounds
Wheat middlings	100	pounds
Ground oats	100	pounds
Gluten feed	100	pounds

Meat scrap	100	pounds
Dried skimmilk	50	pounds
Alfalfa leaf meal	50	pounds
Bone meal	16	pounds
Salt	4½	pounds
Cod liver oil concentrate	1	quart

The Robinson flock was self-fed shelled corn thruout the breeding season and also received in open hoppers a dry mash of wheat mixed feed 300 pounds, ground yellow corn 100 pounds, meat scrap 100 pounds, and salt 5 pounds.

The eggs used in the experiment on embryo growth were produced at the Western Kentucky Substation, Princeton, Kentucky. The eggs were collected for thirteen days and then shipped to Lexington. This flock received a regular laying mash and grain.

1. TEMPERATURE OF THE EMBRYO AND OF THE POULT

To determine the normal temperature of the developing turkey embryo, temperature readings of eggs incubating under favorable environments, were taken daily. Three typical conditions were observed: first, natural incubation, eggs in nests on bluegrass sod (the turkey hen's choice); second, sectional incubator (Jamesway), circulation of the air produced by gravity; third, forced draft incubator (Buckeye). The incubators were operated at the temperature and humidity which had given high hatchability in previous experiments.

The sectional incubator was run at 100½, 101½, 102½, and 103° F., the first, second, third and fourth weeks, respectively, with the bottom of the bulb of the thermometer level with the top of the turkey eggs, that is, 1⅞ inches above the tray. The thermometers were Tycos No. 409 graduated in $^1/_5$ degrees. All thermometers were checked for accuracy before use. The several sections of the incubator seldom varied more than $^1/_5$ degree from the control temperature. The moisture pans in each section were kept filled and the humidity did not vary greatly thruout the incubation period. The relative humidity was checked frequently and varied from 60 percent to 65 percent.

The forced-draft incubator was operated at a temperature

of 99½° and varied from 99° to 100° F. The relative humidity was approximately 59 percent.

The method recommended by Sanctuary (1) was used in the determination of the temperature of the embryos. A small hole was made in the shell with a ¼-inch bolt and the bulb of a clinical thermometer was lowered into the egg to the position of the developing embryo. The thermometer was allowed to remain two minutes or more. Loss of heat from the embryo was prevented by wrapping the egg and thermometer stem in cotton, and protecting them from drafts.

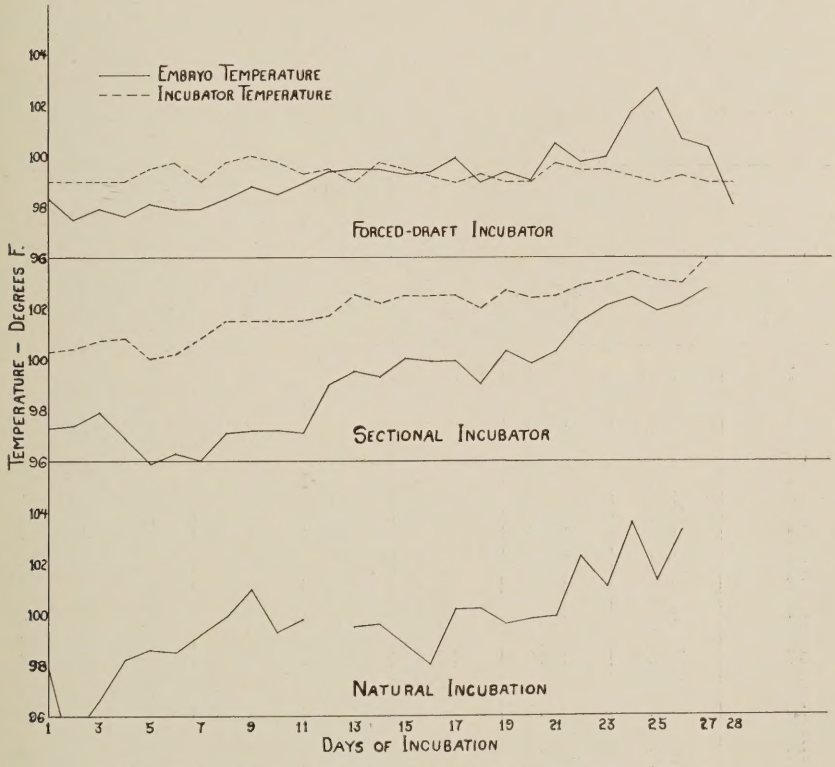

Figure 1. Mean embryo and incubator temperatures.

The embryo temperature curve (Figure 1) for embryos under natural conditions is based on from one to three embryos each day of incubation (51 eggs broken in the 25 days checked). The number of eggs broken for temperature determination was

small because of the difficulty of getting broody turkey hens not needed to produce eggs for other experiments. The curves for embryo temperature under the incubator environment are based on the mean temperature of five embryos taken daily in each machine.

The mean temperature of the turkey embryo, incubated naturally, varied from 92.2° F. to 99.2° F., the first week. There was a rise to 101.0° F., on the ninth day with a comparatively uniform temperature for the remainder of the second week. The third week of incubation also showed only a slight variation, with the exception of the sixteenth day when the temperature was 98° F. There was a sharp rise from 99.9° F., on the twenty-

TABLE 1. DAILY TEMPERATURE OF TURKEY EMBRYOS, IN DEGREES F.

Day of Incubation	Natural Incubation Embryo Temperature	Forced-Draft Incubator			Sectional Incubator‡		
		Embryo Temperature	Temperature of Incubator	Difference†	Embryo Temperature	Temperature at Top of Eggs	Difference†
1	97.9	98.3	99.0	—0.7	97.3	100.3	—3.0
2	92.2*	97.5	99.0	—1.5	97.4	100.4	—3.0
3	96.6*	97.9	99.0	—1.1	97.9	100.7	—2.8
4	98.2	97.6	99.0	—1.4	96.9	100.8	—3.9
5	98.6	98.1	99.5	—1.4	95.9	100.0	—4.1
6	98.5	97.9	99.75	—1.85	96.3	100.2	—3.9
7	99.2	97.9	99.0	—1.1	96.0	100.8	—4.8
8	99.9	98.3	99.75	—1.45	97.1	101.5	—4.4
9	101.0	98.8	100.0	—1.2	97.2	101.5	—4.3
10	99.3	98.5	99.75	—1.25	97.2	101.5	—4.3
11	99.8	98.9	99.25	—0.35	97.1	101.5	—4.4
12	———	99.4	99.5	—0.1	99.0	101.7	—2.7
13	99.5*	99.5	99.0	+0.5	99.5	102.5	—3.0
14	99.6*	99.5	99.75	—0.25	99.3	102.2	—2.9
15	98.8*	99.3	99.5	—0.2	100.0	102.5	—2.5
16	98.0*	99.4	99.25	+0.15	99.9	102.5	—2.6
17	100.2	99.9	99.0	+0.9	99.9	102.5	—2.6
18	100.2	99.0	99.25	—0.25	99.0	102.0	—3.0
19	99.6	99.4	99.0	+0.4	100.3	102.7	—2.4
20	99.8	99.1	99.0	+0.1	99.8	102.4	—2.6
21	99.9	100.5	99.75	+0.75	100.3	102.5	—2.2
22	102.3	99.8	99.5	+0.3	101.5	102.9	—1.4
23	101.1	100.0	99.5	+0.5	102.1	103.1	—1.0
24	103.6	101.8	99.25	+2.55	102.4	103.4	—1.0
25	101.3	102.7	99.0	+3.7	101.9	103.1	—1.2
26	103.5*	100.7	99.25	+1.45	102.2	103.0	—0.8
27	———	100.4	99.0	+1.4	102.8	104.0	—1.2
28	———	98.1	99.0	—0.9	———	———	———

* Only one embryo.

† Difference between mean temperature of embryos and temperature of incubator at time eggs were removed for test.

‡ Gravity circulation.

first day of incubation to 102.3° F., on the twenty-second day. The temperature the fourth week was considerably higher than that of the preceding week.

The mean temperature of the turkey embryos in the forced-draft incubator varied from 97.5°, F., to 98.3° F., the first week, from 98.3° F., to 99.5° F., the second week, from 99.0° F., to 100.5° F., the third week; and from 98.1° F., to 102.7° F., the fourth week of incubation. The embryo temperature was below that of the incubator until the thirteenth day of incubation, continued at approximately that of the incubator until the twentieth day and was appreciably higher than that of the incubator from the twenty-first day until hatching time.

The mean temperature of the turkey embryos in the sectional incubator varied from 95.9° F., to 97.9° F., the first week, from 97.1° F., to 99.5° F., the second week, from 99.0° F., to 100.3° F., the third week and from 101.5° F., to 102.8° F., the final week of incubation. There was a decided increase in the temperature of the embryos on the twelfth day and again on the twenty-second day. The differences between the embyro temperature and the incubation temperature were markedly reduced as the incubation period progressed.

Eggs from the same flocks, hatched in the same incubators operated at approximately the same temperature and humidity gave from 65 to 75 percent hatchability during the same season, which indicated that the embryos used for temperature readings were under favorable incubation conditions.

During the first eleven days of incubation, the embryos in the sectional incubator were from 2.8° F., to 4.8° F., below the temperature of the incubator as indicated by a thermometer with its bulb level with the top of the eggs. On the twelfth day, the difference was reduced to 2.7° F., and varied from 2.2° F., to 3.0° F., from the twelfth thru the twenty-first day. The rise in embryo temperature followed the rise in incubator temperature at the end of the first week, preceded the thirteenth day rise and accompanied the twenty-first day rise in incubator temperature. The difference became less as incubation progressed. As the embryos grew, the heat produced by metabolic

processes increased and reduced the amount of difference between the temperature of the incubator and the embryos.

In the forced-draft incubator, the embryos remained from 0.7° F., to 1.8° F., below the incubator temperature the first ten days. From the eleventh thru the twenty-third day, the embryo temperature varied slightly below and above the incubator temperature. On the twenty-fourth day the embryo temperature rose above the incubator temperature and remained so until the twenty-eighth day. On the twenty-eighth day, the temperature of embryos in pipped eggs was slightly below incubator temperature. This was doubtless caused by evaporation from the wet poults as yet unhatched.

The body temperature of poults just out of the shell was practically the same as that of the temperature within the shell of the pipped eggs, which shows that the temperature of the

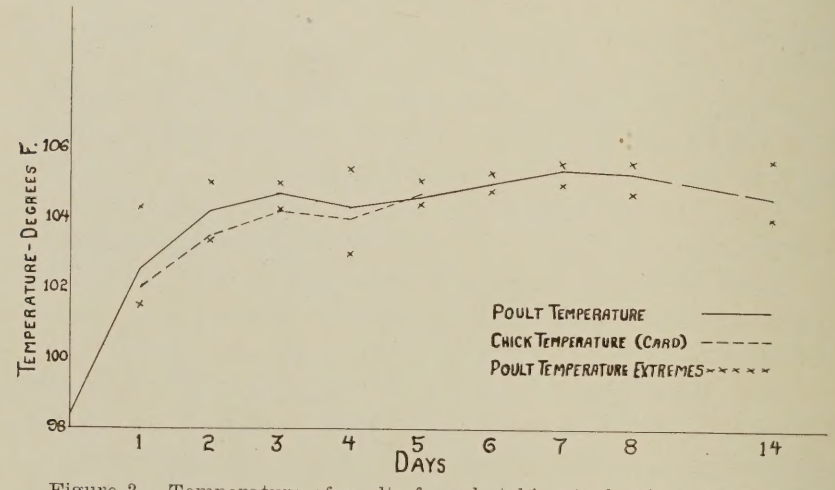

Figure 2. Temperature of poults from hatching to fourteen days of age, compared with chick temperature.

entire body, not just that of the surface of the poult, was lowered at hatching time. There was a sharp rise in the body temperature of the poult (Figure 2) during the first and second days after hatching. The temperature, which was taken rectally, reached its maximum on the seventh day when it was 105.4° F.

The graph represents the mean temperature of five Bronze

poults taken daily thru the first eight days and on the fourteenth day. Daily temperatures were taken also of five White Holland poults, but no significant breed differences were noted. There was a slight drop (0.7° F.) during the second week, as the mean temperature was 104.6° F. on the fourteenth day.

Since the body temperature of the chick varies with the time of day, according to Card (2), all temperature readings for the poults were taken at about 4 p. m. Card's work also showed no significant differences in the sexes, except the third and fourth days, from 0.5° F., to 0.8° F., so poults of both sexes were used in the determinations. It will be noted from Figure 2 that the body temperature of the Bronze turkey poult was slightly above that of the White Leghorn chick (Card's data, mean of both sexes) up to the fifth day, when the two were about the same. That the body temperature of the chick in early life should overtake that of the poult is to be expected as the temperature of the adult fowl exceeds that of the mature turkey, according to Fronda (3) who gave 106.0° F., as normal for the adult turkey and 106.7 F., for the mature chicken. He also took the readings thruout the day and found that the adult male and female turkey reach their maximum body temperature at 4:00 p. m. The mean temperature was approximately 106.6° F., which was two degrees higher than the mean of 104.6° F., which we found for two-weeks-old poults. The place in the growth curve where this decided increase occurs is yet to be determined.

2. GROWTH OF THE TURKEY EMBRYO (4)

The determination of causes of embryo mortality seems to be dependent in a measure upon accurate knowledge of the metabolism of the developing embryo. A review of the literature of this subject is given by Needham (5).

Scott and Hughes (6) determined the rate of growth of Bronze turkey embryos by wet weight, dry weight, and nitrogen content. They found that the turkey embryo was much smaller than the chicken embryo at any given day of incubation up to the twenty-first day.

This study of the Bronze turkey embryo covers: embryonic growth as measured by wet weight, dry weight, and ash content; percentage of moisture; growth cycles; and calcium and phosphorus content.

The eggs were incubated in an electric incubator (Petersime) at an average temperature of 99¾° F. and a relative humidity of 64 percent. All eggs were turned four times daily. At twenty-four intervals, six eggs were removed and stored in a refrigeration room at 28 to 30° F. This effectively stopped embryonic development and preserved the eggs, which were analyzed later. The procedure for analysis was as follows: The embryos were removed from the eggs, compared with previously standardized specimens, freed of all adhering yolk, including that within the body cavity, dried on filter paper, transferred to

TABLE 2. AVERAGE WEIGHT, MOISTURE AND ASH CONTENT OF THE TURKEY EMBRYO.

Day	Average Weight of Eggs	Number of Embryos	Wet Weight grams	Dry Weight grams	Percent Moisture	Ash Content grams
5	84.2	5	.0156	.0050	67.95	
6	84.5	2	.0330	.0104	68.48	
7	83.5	4	.0797	.0204	74.40	.0004
8	83.7	3	.1903	.0279	85.34	.0013
9	84.5	2	.5121	.0586	88.56	.0044
10	86.3	3	.5823	.0576	90.11	.0043
11	82.5	2	.9492	.0719	92.43	.0085
12	82.5	4	1.7670	.1583	91.04	.0138
13	83.0	5	3.9664	.2719	93.15	.0269
14	82.7	6	4.4310	.3715	91.62	.0319
15	83.7	3	5.6975	.6530	88.54	.0523
16	85.6	5	6.2538	.9141	85.38	.0669
17	84.8	6	7.0468	1.2354	82.47	.0865
18	81.0	2	12.1482	2.2035	81.86	.1501
19	83.7	3	15.4144	3.1686	79.44	.1923
20	84.5	4	16.5000	3.2900	80.09	.2175
21	83.5	4	23.8900	4.8200	79.81	.3250
22	84.0	4	27.5100	5.8200	78.86	.3950
23	85.8	5	33.2100	6.8600	79.35	.4900
24	83.4	5	36.9300	7.8900	78.63	.5840
25	85.0	5	44.3600	9.2900	79.05	.6900
26	84.2	5	49.3600	11.3700	76.96	.7920

silica dishes, weighed, and dried to constant weight in an electric oven at 100° C. The dry embryos were then burned to a white ash, which was dissolved in hydrochloric acid, made to a definite volume with distilled water, and calcium and phosphorus determined in separate aliquots. Calcium was deter-

mined by the McCrudden volumetric method (7) and phosphorus by the volumetric method of the Association of Official Agricultural Chemists (8).

Growth of the turkey embryo as measured by wet weight, dry weight, percent of moisture, and ash content is given in Table 2 and Figure 3. As shown in Figure 3, embryonic growth

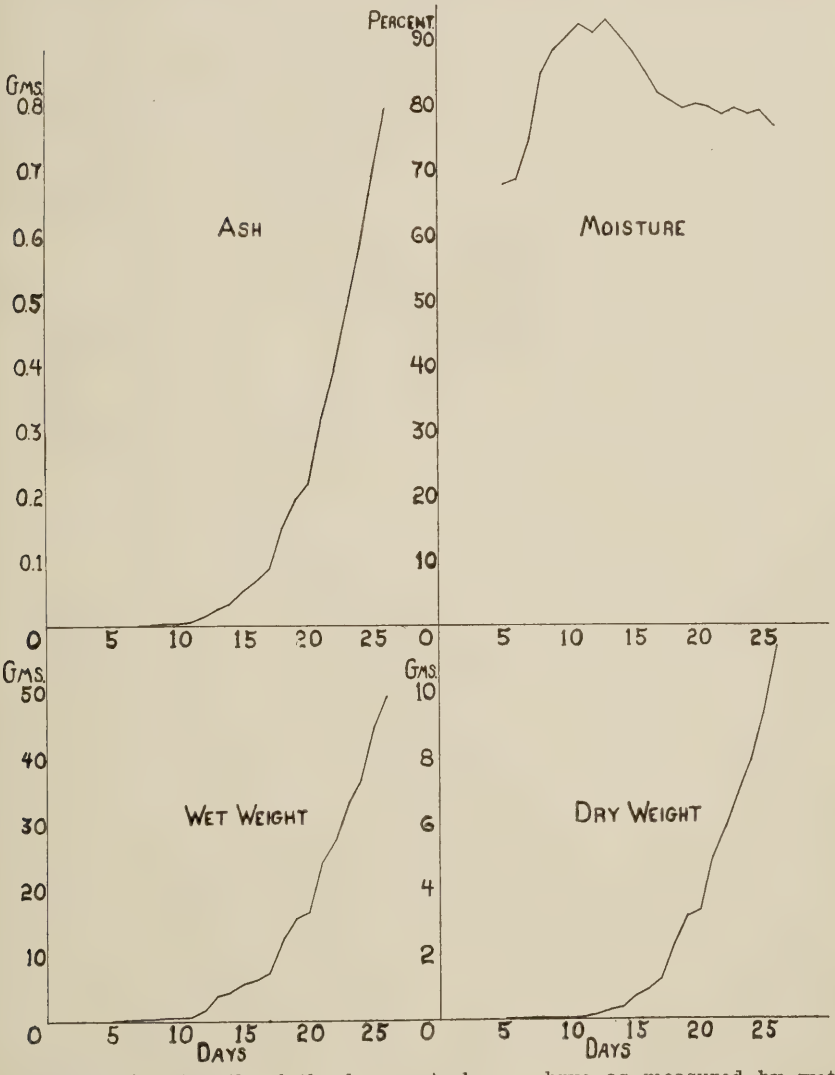

Figure 3. Growth of the bronze turkey embryo as measured by wet weight, dry weight, ash and percent moisture.

is divided into three distinct phases with definite periods of retardation between the ninth and tenth days and between the nineteenth and twentieth days. Romanoff (9) comparing his data with those of other investigators, found three distinct cycles in the growth of the chick embryo, retardation of growth usually falling on the ninth and sixteenth days of incubation. The periods of retardation of growth in the turkey embryo appear at relatively the same time as those of the chick embryo.

The calcium and phosphorus content of the turkey embryo is given in Table 3. The actual amount of calcium is small until the eighteenth day, after which, with the exception of the decrease apparent on the twentieth day, it is deposited so as to

TABLE 3. AVERAGE CALCIUM AND PHOSPHORUS CONTENT OF TURKEY EMBRYOS.

Day	Calcium (Ca) grams	Phosphorus (P) grams	Ca:P ratio
13	.0031	.0042	.74:1
14	.0031	.0057	.54:1
15	.0057	.0085	.67:1
16	.0092	.0118	.78:1
17	.0119	.0143	.83:1
18	.0207	.0274	.76:1
19	.0409	.0289	1.42:1
20	.0321	.0222	1.45:1
21	.0543	.0534	1.02:1
22	.0764	.0664	1.15:1
23	.0928	.0812	1.14:1
24	.1081	.0948	1.14:1
25	.1388	.1160	1.20:1
26	.1632	.1327	1.23:1

increase its total rapidly. The total calcium corresponds to the growth of the embryo. Needham (10) finds that the calcium content of turkey embryos agrees exactly with that for calcium content of other embryos.

The calcium and phosphorus of the embryos decreased simultaneously from the nineteenth to the twentieth days and were approximately the same on the twenty-first day. The calcium-phosphorus ratio with phosphorus remaining constant at 1.0 is shown in Table 3. Until the nineteenth day the value of calcium is below 1.0 while after that time the value is more

than 1.0. The calcium-phosphorus ratio during the latter period of incubation (approximately 1.2 Ca:1.0 P) may be an indication of the proper ratio in the diet of newly hatched turkeys.

3. DISTRIBUTION OF EMBRYO MORTALITY (11)

Payne (12) found that there were two critical periods during the incubation of chicken eggs. These periods of high mortality occur on the fourth, fifth and sixth days and on the eighteenth, nineteenth and twentieth days of incubation. The critical periods coincided in natural and artificial incubation.

Byerly (13) noted the occurrence of a minor peak of mortality in chicken embryos on the seventh day of incubation, and Byerly, Titus and Ellis (14) found a mid-incubation peak related to nutritional deficiencies in the diet of the breeding flock.

Riddle (15) found that embryo mortality of the common pigeon, ring dove, and wild dove, when plotted on the same basis as that of chickens (Payne's data) showed the same peaks of mortality during the early and late periods of incubation. The distribution of turkey embryo mortality has not been reported heretofore, so far as the authors are aware.

In this experiment, in which mortality of the turkey embryo is compared with that of the chick, some of the eggs were incubated in a forced-draft electric incubator (Smith 30,000 egg capacity) and the others in a sectional hot water incubator heated by gas (Jamesway triple deck). The forced-draft incubator was operated at a temperature of 99° F., with a relative humidity of 61 per cent until the twenty-fifth day of incubation and 70 percent thereafter until the hatch was completed.

The eggs were subject to four different procedures, namely: group 1, candling and removal of infertiles and dead germs on the twenty-fifth day; group 2, no candling; group 3, candling and distributing eggs equally to two trays for hatching; and group 4, candling but not dividing. The hatchability was practically the same for all four lots. The mortality figures have been grouped for this study. The sectional incubator was operated with the thermometer bulb 1⅞ inches above the tray at a

temperature varying from 100½° F., for the first week to 103° F., the third week.

All eggs candled out (infertile or dead germ) on the twenty-fifth day and those that failed to hatch were broken and compared with previously standardized embryos to determine the age at death. There were 961 dead embryos in the White Leghorn hen eggs, 489 in Bronze turkey eggs incubated in the forced-draft incubator, and 310 in those in the sectional incubator. The numbers are sufficient to yield fairly dependable results.

The distribution of embryo mortality for Bronze turkey eggs contrasted with that of Single Comb White Leghorn hen eggs (no pullet eggs) is plotted in Figure 4. It should be noticed that the percentage mortality of the two groups of turkey eggs is very similar. In turkey eggs, as in chicken eggs, there is a critical period early in embryonic life and a second critical period during the latter part of incubation. The peak of the first critical period occurs on the fourth day of incubation and that of the second on the twenty-fifth day. Mortality between these periods is low. The second peak of mortality occurs at the same relative time for turkey and chicken eggs, but there is a difference in the first peak which may be caused by the greater length of time required to heat the turkey eggs to incubation temperature.

The percentages of hatchability and of malpositions are given in Tables 4 and 5. The figures given for turkey eggs incubated under the two sets of conditions are not strictly com-

TABLE 4. PERCENTAGE HATCHABILITY.

	Number Fertile Eggs	Number Poults or Chicks	Percent Hatchability
Turkey eggs (forced-draft incubator)	2693	2116	78.6
Turkey eggs (sectional incubator)	1680	1258	74.9
Chicken eggs (forced-draft incubator)	3465	2504	72.3

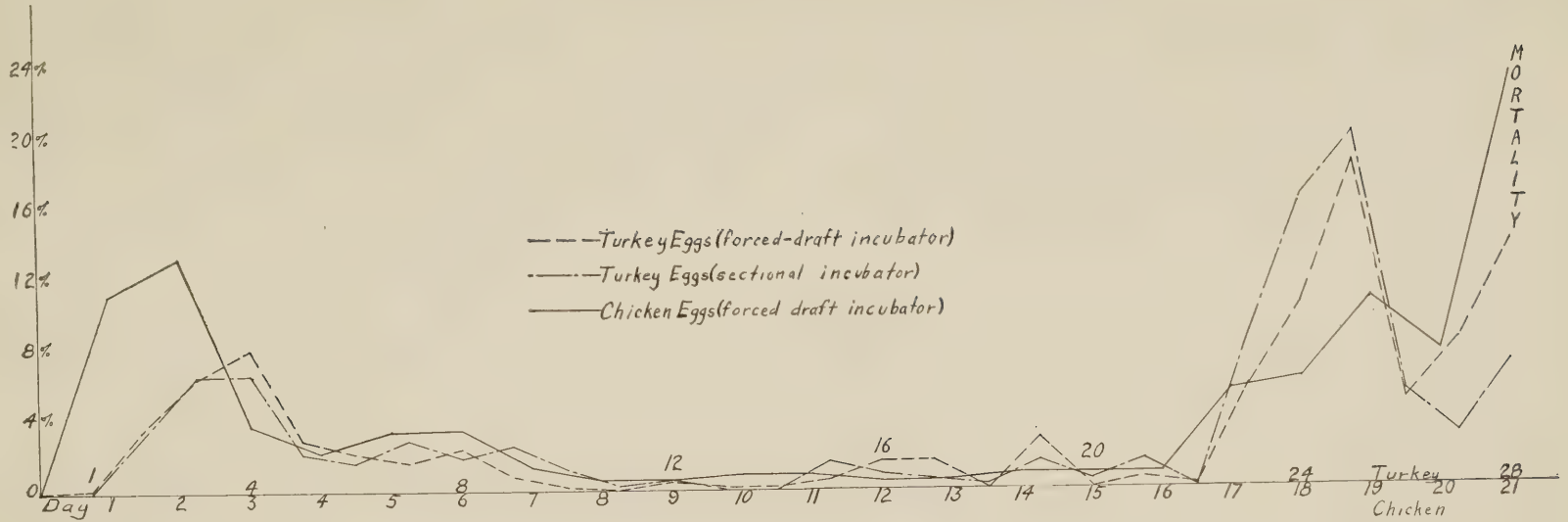

Figure 4. Distribution of embryo mortality in turkey and chicken eggs.

parable, for the eggs were not incubated at exactly the same time. They may be used, however, to illustrate the possible occurrence of these malpositions under each of the environmental conditions involved. It should be noted particularly that the incidence of malposition 2, head-in-small-end-of-egg, was

TABLE 5. FREQUENCY OF MALPOSITIONS.

Malposition	As percentage of all fertile eggs			As percentage of all dead germs		
	Turkey Eggs		Chicken Eggs	Turkey Eggs		Chicken Eggs
	Forced-Draft Incubator	Sectional Incubator	Forced-Draft Incubator	Forced-Draft Incubator	Sectional Incubator	Forced-Draft Incubator
1. Head between thighs	0.59	0.89	1.67	3.29	4.84	6.04
2. Head in small end of egg	0.48	1.37	0.14	2.66	7.42	0.52
3. Head to left and under left wing	0.15	0.24	1.41	0.82	1.29	5.10
4. Embryo rotated in egg away from air cell	0.04	0.00	0.03	0.20	0.00	0.10
5. One or both feet over head	3.71	2.20	2.94	20.45	11.94	10.61
6. Beak over right wing	0.26	0.12	0.17	1.43	0.65	0.62
7. Both 2 and 5	0.34	2.26	0.00	1.85	12.26	0.00
8. All others	0.57	1.25	0.29	3.08	6.78	1.04
Total	6.14	8.33	6.65	33.78	45.18	24.03

much greater than in the sectional incubator and that the occurrence of malposition 5 was high in both incubators, altho more so in the forced-draft machine.

4. EFFECT OF DIFFERENCES IN TEMPERATURE ON HATCHABILITY (16)

The temperature that gives best results for chicken eggs is usually recommended for the incubation of turkey eggs. Graybill (17) suggested that the temperature be "maintained as nearly as possible at 103° F.", but he does not state the position of the thermometer.

Scott (18) incubated turkey eggs at 98° F., in lot 1; 90° F., in lot 2; 100° F., in lot 3; and 101° F., in lot 4, for the first week, and the temperature was raised one degree each successive week in all lots. The percentage hatch of fertile eggs in trial one was 71.4, 69.4, 81.6 and 75.0, for lots 1, 2, 3 and 4 respec-

tively. In trial two, the percentage hatch of fertile eggs was 54.9, 61.5, 78.4 and 58.3, for the same lots. On the basis of this work, the Kansas Station (19) recommended a temperature of 99° F., in a forced-draft machine and 100°, 101°, 102°, and 103° F., for the first, second, third and fourth weeks respectively for the sectional type, the bulb of the thermometer resting on a level with the top of the turkey eggs.

Mussehl (20) suggested that the best results may be obtained with sectional incubators when the temperature at the top of the egg is maintained at from 102° to 103° F., which insures an average of the temperatures at the bottom of the eggs of about 100° F., or slightly below. The recommendation for the forced-draft incubator was 99¾° to 100° F.

Burr (21) in reporting trials with turkey eggs stated that "the machines were run at 103 or slightly under". Presumably, he referred to incubators in which circulation was produced by gravity. The position of the thermometer was not given.

The Oklahoma Station (22) recommends 99½° to 100° F., for the forced-draft incubator and 102° to 103° F. at the level of the top of the eggs for the sectional type.

Mussehl and Ackerson (23) found that the rate of air movement and humidity seemingly exerted a greater influence on hatchability during the last four days than during the first twenty-four days of incubation. Higher hatchability was procured when the eggs were transferred on the twenty-fourth day of incubation from a forced-draft type incubator to a gravity-ventilated machine.

McFarlane, Lloyd and Merrill (24) recommended the same heat requirements for turkey egg incubation as for chicken eggs. Their temperature recommendations were that the incubator should be run at 102° F., with the bulb of the thermometer placed just above the contact point of the eggs. They suggest that the temperature may be allowed to increase to 103° or 104° F., during the time the poults are hatching.

Romanoff (25) incubated* turkey eggs for three weeks at

* In a forced-draft type incubator.

99.5° F., with about 65 per cent relative humidity. During the latter part of incubation, the eggs were transferred to incubators with temperatures ranging from 86.9° F. to 106.7° F. His results showed that hatchability was best at fourth-week temperatures of from 96.8° to 100.4° F. The number of crippled poults at hatching progressively increased with decrease of temperature below normal. The poults which hatched at temperatures of 97.7° F. and 99.5° F. grew well with low mortality, while the groups hatched at higher or lower temperature showed high mortality. It was also noted that the greatest embryo mortality occurred on the fifth and twenty-fifth days.

In our experiments, 2691 eggs from Bronze turkeys were distributed among four lots incubated at the following mean temperatures:†

Lot	First Week	Second Week	Third Week	Fourth Week
1	100.5	101.4	102.6	103.0° F.
2	101.0	101.9	102.9	103.4° F.
3	101.3	102.0	102.7	103.1° F.
4	100.9	101.1	101.3	101.4° F.

The sectional incubator (Jamesway), in which the circulation of air is produced by gravity, was used. The incubator was in a basement with concrete walls and floor. Water pans the full size of the compartment, were placed in the incubator on the day the eggs were set and contained water during the entire period of incubation. Thermometers which had been tested for accuracy were placed with the bottom of the bulb 1⅞ inches above the egg tray, one in each compartment. Previous measurements showed this to be the average height (short axis) of the turkey eggs when on their sides. Cloths were placed in the hatching trays on the twenty-fifth day of incubation, on which day the eggs were candled. The relative humidity calculated daily for one section of the incubator varied from 58 to 65 percent. The eggs were turned five times daily.

The fertility in all four groups was high, that is, from 85.2

† The figures are the mean of all the readings (3 to 5 daily). The operator endeavored to control lot 1 at 100½, 101½, 102½, 103, lot 2 at 101, 102, 103, 103½, lot 3 at 101½, 102, 102½, 103, and lot 4 at 101, 101, 101, 101 degrees F., during the 1st, 2nd, 3rd and 4th weeks, respectively.

percent to 88.7 percent. A study of the hatchability of the four lots (Table 6) indicates that 101° F. thruout the hatch (lot 4) hardly supplies sufficient heat for the best results (70.5 percent hatchability) whereas a mean temperature of 103.4° F. (lot 2) the last week supplies more than the optimum amount of heat (68.7 percent hatchability). Obviously, the optimum temperature for incubating turkey eggs in a sectional incubator, bulb on a level with the top of the eggs, lies between 100½° and 103° F., since the best hatches were in lots 1 and 3. However, whether there is any advantage in starting incubation as low as 100½° or 101° F. remains for further experiments to determine. That a mean temperature of 103.4° F. the fourth week of incubation is detrimental to the developing embryos is clearly shown in

TABLE 6. EFFECT OF TEMPERATURE ON HATCHABILITY AND DISTRIBUTION OF MORTALITY OF TURKEY EGGS (SECTIONAL INCUBATOR).

	Lot 1	Lot 2	Lot 3	Lot 4
Fertile eggs	641	659	548	491
Strong poults hatched	496	453	416	346
Percentage of hatchability	77.4	68.7	75.9	70.5
Mortality, first week	5.0	6.4	4.2	4.3
Mortality, second week	1.4	2.1	0.9	1.4
Mortality, third week	1.1	1.4	1.3	1.8
Mortality, fourth week	9.2	16.4	12.6	12.6
Mortality, total	16.7	26.3	19.0	20.1
Percentage of weak poults*	5.9	5.0	5.1	9.4
Mean temperature, first week	100.5	101.0	101.3	100.9
Mean temperature, second week	101.4	101.9	102.0	101.1
Mean temperature, third week	102.6	102.9	102.7	101.3
Mean temperature, fourth week	103.0	103.4	103.1	101.4

* Weaklings and spraddle-leg poults.

Table 6. It should be noted that the highest weekly mortality, 16.4 percent of fertile eggs, was in lot 2 during the fourth week of incubation. Since this lot showed no higher mortality the third week than lot 3, which received only a slightly lower temperature that week, obviously the decided increase in embryo mortality the last week was caused by heat above the optimum.

5. EFFECT OF POSITION ON HATCHABILITY (16)

Certain manufacturers of cabinet incubators have recently recommended hatching chicken eggs on end. The egg trays are transferred on the eighteenth day to the hatching section with-

out the eggs being candled. By the use of this method, the manufacturers find not only a saving of labor, but an actual increase in hatch. To test this method of hatching with turkey eggs, eight trays of eggs were hatched, large end up, in an electric, 30,000 egg capacity, forced-draft incubator (Smith). The trays were left full, that is, 111 to 116 eggs per tray as set, and the eggs were not candled. An equal number of trays of eggs was candled on the twenty-fifth day and the remaining eggs hatched on their sides.

In the first hatch of this series, it was noted that the poults emerged from the shells with great difficulty when the eggs were on end and several poults died from exhaustion. Hence it was decided to "skim" both groups as the hatch progressed, that is, to remove both the loose shells and the newly hatched poults every few hours. This additional labor more than offset the labor saved by not candling on the twenty-fifth day. Hatchability was practically the same under both conditions, 79.2 percent when the eggs were not candled and 77.9 percent when they were candled. Hence, the hatching of uncandled eggs, large end up and trays full, is not recommended for turkey eggs.

The weekly distribution of embryo mortality indicated in Table 7 shows no difference in the two lots the last week and all

TABLE 7. HATCHABILITY OF TURKEY EGGS UNDER DIFFERENT TREATMENTS (FORCED-DRAFT INCUBATOR*).

	Candled	Not Candled	90-96 Eggs to Each Hatching Tray	45-48 Eggs to Each Hatching Tray
Fertile eggs	818	784	540	551
Strong poults hatched	637	621	427	431
Percentage of hatchability	77.9	79.2	79.1	78.2
Percentage of mortality, first week	5.4	3.7	5.2	4.4
Percentage of mortality, second week	1.0	0.5	1.1	0.5
Percentage of mortality, third week	1.6	1.4	0.9	1.3
Percentage of mortality, fourth week	12.6	13.5	9.1	8.9
Percentage of mortality, total	20.6	19.1	16.3	15.1
Percentage of weak poults	1.5	1.7	4.6	6.7

* Smith incubator, operated at temperature of 99° F., relative humidity 61 percent until twenty-fifth day of incubation and 70 percent thereafter until hatch completed.

the eggs were incubated and handled under identical conditions up to the twenty-fifth day of incubation.

In another series, the eggs on the trays after candling, approximately 95 to 100 eggs per tray, were compared with eggs on other trays which after candling were distributed between two trays for hatching. This gave approximately 47 to 50 eggs for each tray. The additional room had no effect on hatchability, as shown in Table 7; the dividend trays gave 78.2 percent hatchability and the undivided trays 79.1 percent, not a significant difference. Obviously, the additional ventilation of the eggs and the additional room for the newly hatched poults was of no benefit. The distribution of the embryo mortality by weeks showed no significant difference between these two lots in any of the four weeks. The incubation conditions were identical to the twenty-fifth day. It should be mentioned that the incubator was only partly filled with eggs at the time the experiment was run, which provided ample air supply for all trays. The results are applicable to commercial conditions, as it is seldom that the hatchery is crowded for space at the end of the chick-hatching season, when most of the turkey eggs are incubated.

6. DISCUSSION

There seems to be a direct relationship between embryo temperature and growth in the turkey embryo. Under natural incubation there was a definite decrease in temperature from the ninth to tenth days. At the same time under artificial incubation there was a definite retardation in growth. The same situation is apparent close to the nineteenth and twentieth days, both in temperature and growth. These periods of retardation appear at approximately the same relative time as those appearing on the ninth and sixteenth days for the chick embryo.

Needham (5) has shown that during the early period of incubation up to and including the seventh day, the chick uses carbohydrates as the source of energy. This period corresponds to the first nine days of the turkey embryo's life and it will be noted that the retardation of growth between the ninth and

tenth days probably marks the limit of this phase of embryonic metabolism.

The second period of retardation which occurs between the nineteenth and twentieth days shows a decided pause in dry weight, wet weight and ash content. Needham has discussed the utilization of protein during the period from the seventh to the sixteenth day of incubation in the chick embryo and the metabolism of fat thereafter. The break in the curve of the turkey embryo corresponds to the change in materials metabolized.

From a study of the mortality curves, the conclusion seems plausible that practices which are effective in decreasing mortality during the critical periods in the incubation of chicken eggs should be effective in improving hatchability in the incubation of turkey eggs. Among these practices are, the proper control of humidity, temperature, ventilation and the turning of the eggs. Humidity should be increased by the addition of moisture on the twenty-fifth day of incubation without waiting for direct evaporation from the pipped eggs and shells of newly hatched poults, since such evaporation tends to increase the number of poults which stick in the shell.

High humidity before the final period of incubation may cause a sticky hatch if it is associated with a temperature above normal. A decrease in mortality during the first critical period may be difficult to obtain, since causes of this mortality are rather obscure. Riddle (15) suggests that this mortality is probably associated with failures in respiratory adjustment. Insko and Martin (26) found some decrease during the early period when there was an increase in the number of times the eggs were turned.

7. SUMMARY

1. The mean temperature of the embryo in turkey eggs being incubated naturally was 98.3° F. the first week, 99.9° the second, 99.5° the third, while the daily average varied between 101.1° and 103.6° the fourth week.

2. In a forced-draft incubator operated at 99½° F. the embryo temperature was below that of naturally incubated tur-

key eggs thruout a large part of the incubation period. At the beginning of the second week there was a rise and then little change until early in the 4th week, when there was another sharp rise.

3. In a sectional incubator operated at 100½, 101½, 102½, 103° F. (bulb level with top of turkey eggs) the turkey embryo temperatures were below both the other groups during the first two weeks. Embryos in this group also showed a sharp rise at the beginning of the fourth week.

4. The actual daily increase in wet weight, dry weight and ash content was very small until the twelfth day, when there was a noticeable increase.

5. The increase in amount of calcium and phosphorus in the embyro was relatively slow until the seventeenth day of incubation.

6. The calcium-phosphorus ratio was less than 1:1 until the eighteenth day of incubation, after which it exceeded 1:1.

7. Growth of the turkey embryo is divided into three distinct phases, with definite periods of retardation between the ninth and tenth and between the nineteenth and twentieth days.

8. The calcium content of the embryo may be used as a measure of growth provided the yolk material drawn into the body cavity is removed before analysis.

9. Two critical periods of embryo development were observed, one centering about the fourth and the other about the twenty-fifth day of incubation.

10. The peaks of turkey embryo mortality occur at comparable periods of incubation for both turkey and chicken eggs.

11. Incubation practices which tend to lessen mortality of chick embryos should be applicable to the incubation of turkey eggs with favorable results.

12. In a sectional incubator, the highest hatchability with turkey eggs was observed when the average temperature was 100.5°, 101.4°, 102.6°, 103° F., the first, second, third and fourth weeks, respectively (bulb of thermometer level with top of eggs).

13. A temperature of 101° F. during the incubation period did not give high hatchability.

14. A temperature above 103° F. the fourth week of incubation increased the embryo mortality that week.

15. Hatching turkey eggs large end up in a forced-draft incubator (trays full) without candling did not increase the hatch and necessitated extra labor at hatching time to avoid loss of poults.

16. With the hatching trays of a forced-draft incubator comfortably filled with eggs resting on their sides nothing was gained by reducing the number of eggs per tray to half and thereby allowing more room and air for the newly hatched poults.

8. PRACTICAL RECOMMENDATIONS

In the light of the experiments reported herein and other incubation research with turkey eggs, principally that of Mussehl (20, 23), Scott (18, 27), Lampman (28), Marsden (29), and Goff (30), the following practical recommendations are given:

1. Turkey eggs should be gathered at least once daily, and stored in a cool place between 40 and 60° F. until set.

2. If turkey eggs are to be held a week or longer they should be turned daily.

3. Egg cases, equipped with duck-egg fillers, hold 200 turkey eggs and are quite satisfactory for holding and turning turkey eggs.

4. It is best to set turkey eggs within a week to 10 days after laying, altho they will hatch well if held under the best conditions as long as three weeks.

5. When incubating turkey eggs in a forced-draft incubator, run the machine at the temperature which has given the best hatches with chicken eggs.

6. In a sectional incubator the best hatches were secured when the machine was run at 100½, 101½, 102½, 103° F., the first, second, third and fourth weeks, respectively. The bottom of the bulb of the thermometer was 1⅞ inches above the egg tray, that is, even with the top of the turkey eggs.

7. Turkey eggs require as much moisture during incubation as chicken eggs, if not more, especially during the last three days of incubation. The relative humidity should be about 60% until just *before* the eggs pip, when it should be increased to 70%. If the forced draft incubator is run at 99½° F. (dry bulb) this means a wet bulb temperature of about 88° F., until the twenty-fifth day and 90 to 91° F., while the eggs are hatching.

8. Observation of the size of the air cell in the large end of the egg, by means of an egg candler, gives the operator a guide on the rate of evaporation. If the incubator has insufficient moisture, the air cell increases in size too rapidly.

9. Turkey eggs should be turned * at least four times daily, from the second thru the twenty-fourth day of incubation. The turnings should be evenly spaced from early morning until the last turning at night. If the eggs are turned an odd number of times (say five) daily, they will not remain in the same position overnight on any two successive nights.

10. Faulty incubation frequently results in weakened poults. These physical handicaps may last several days and later cause mortality sometimes attributed to other factors such as feed, brooding temperature, litter and the like.

11. Strong, vigorous poults that may be raised with a very low brooding mortality can be hatched artificially.

12. Artificial incubation will increasingly play a large part in the development of the turkey industry, since sufficient experimental work has been done to show that turkey eggs hatch well in most well-built incubators, if properly managed.

13. Until experimental results indicate the desirability of a change, it is wise to follow with turkey eggs those incubation procedures that have given the best hatches with chicken eggs.

* In the sectional incubator it is desirable to rotate the turning crank over, back and over, so that the turning device passes across the tray, then back and across again at each turning. This insures all eggs being turned.

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